



VU Research Portal

Assessment of capacity in infrastructure networks

Kreutzberger, E.; Nijkamp, P.; Vleugel, J.

1992

document version

Publisher's PDF, also known as Version of record

[Link to publication in VU Research Portal](#)

citation for published version (APA)

Kreutzberger, E., Nijkamp, P., & Vleugel, J. (1992). *Assessment of capacity in infrastructure networks*. (Serie Research Memoranda; No. 1992-58). Faculty of Economics and Business Administration, Vrije Universiteit Amsterdam.

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

Take down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

E-mail address:

vuresearchportal.ub@vu.nl

Serie Research Memoranda

Assessment of Capacity in Infrastructure Networks: A Multidimensional View

E. Kreutzberger
P. Nijkamp
J. Vleugel

Research-Memorandum 1992-58
December 1992



**Assessment of Capacity in Infrastructure Networks:
A Multidimensional View**

E. Kreutzberger

Technical University
Research Institute for
Policy Sciences &
Technology
Delft
The Netherlands

P. Nijkamp & J.M. Vleugel

Free University
Faculty of Economics &
Econometrics
Dpt. of Regional Economics
Amsterdam
The Netherlands

Paper presented at the **Sixth World Conference on Transport
Research** in Lyon, June 29-July 3, 1992



Introduction

In this paper the concept of capacity management in infrastructure policy is developed. The paper has the following contents. In Section 1 a general introduction in infrastructure planning and management is given, while Section 2 concentrates on the use of scenarios of preconditions (constraints) for the use of infrastructure capacity. Section 3 is of a more practical nature, since this section contains various applications of the scenarios. Section 4 gives an overview of major conclusions.

1 Infrastructure as a Source of Conflicts

Network infrastructures have to serve the needs of a mobile society in which mobility/interaction of goods, persons and information are the clear exponents of a modern network economy (see ECMT, 1986; Nijkamp et al., 1990). In the past decades new infrastructure expansions and investments have by and large followed the demand requirements; transport policy was mainly demand driven and investments in transport infrastructure followed mainly the demand trends. Only the 'jumps' in the system (e.g., airplanes, high speed trains etc.) were also caused by technology push motives.

However, the question facing us nowadays is more complicated: if we take for granted the politically advocated and largely accepted objective of ecologically sustainable economic development, are then the needs of an extremely mobile network society for a drastic expansion of infrastructure compatible with the constraints imposed by environmental concerns, safety considerations and socio-economic equity objectives?

The answer to this question has far reaching consequences. The conflicting nature of a demand driven transport system provokes immediately the question as to the role of supply in terms of managing and expanding infrastructure. Here the fundamental question is: are ecological, safety and equity considerations prohibitive regarding network expansion? If so, then the question of capacity use of the existing material infrastructure in Europe has to be given due attention. If not, the question remains nevertheless whether a better use of existing capacity may not be an economically more viable option than an uncritical investment effort in conventional physical infrastructure.

Furthermore, the problem of capacity constraints should not only be considered from the viewpoint of separate bottlenecks in a given infrastructure component, but also - and even more important - from the viewpoint of the functioning of a network as a whole. Thus also the relationship between infrastructure development and its use on the one hand and the modal split on the other hand is at stake here. This question also leads to complex trade-offs between investments and disinvestments at the same time in the transport sector. Transport policy should - in this context - serve to enhance efficiency and sustainability from the viewpoint of network

operations (see also ERT, 1991). Thus an important related question is: what kind of network policy can be feasibly developed so as to serve simultaneously the needs of a mobile society, the ecological paradigm and the socio-economic needs of the mobility-deprived?

The previous questions make it evident that the notion of capacity and the idea of network management are critical parameters for a policy analysis of new infrastructures in Europe. In this paper we will in particular call attention for the need for effective, efficient and creative capacity management of existing material infrastructure (including the need for a high-tech upgrading of and a more market-oriented view on such networks).

2 Mobility and Infrastructure; Capacity and Use under Preconditions

Mobility and transport are not an aim in itself, but serve the goal of economic growth and welfare increase. However, there is not a linear correlation between mobility and transport on the one hand and economic development on the other. There is essentially a conflict between three major policy orientations:

- economic development, requiring infrastructure efficiency
- environmental sustainability, caused by the 'ecological paradigm'
- network access, imposed by the needs of mobility-deprived.

Depending on the size of transport flows, the specific modal split in a network, the vehicle technology used and the type of regulations, this conflict is more or less present in actual situations.

It is evident however, that the above conflicts are becoming more serious, as more traditional infrastructure investments - in combination with more traditional mobility processes - are allowed and realized. In this sense, a straightforward linear expansion of traditional transport systems is incompatible with sustainability and socio-economic/spatial equity considerations (see also Himanen et al., 1991). Whether or not this is politically acceptable, is a different question which apparently is given different answers in European countries.

In order to come to grips with the above mentioned conflictual issues, it seems plausible to investigate the critical success factors for the planning and implementation of transport systems. In this context reference can be made to the so-called pentagon model which has been used elsewhere to analyze and evaluate new European transport plans (see inter alia Maggi and Nijkamp, 1991, and Vleugel and Nijkamp, 1991). The edges of the pentagon (see Figure 1) represent five critical success factors for designing and operating transport systems.

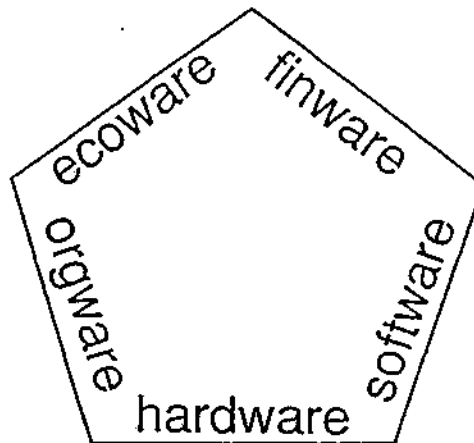


Figure 1. The pentagon with critical success factors

These five factors have the following meaning:

- hardware (e.g., efficient technological standardisation);
- software (e.g., use of compatible information systems);
- orgware (e.g., existence of effective management structures);
- finware (e.g., presence of private or public financial institutions);
- ecoware (e.g., environment-friendly or regulated systems).

This prism model may be particularly useful in evaluating new transport policies. Today several projects concerning transport infrastructure or transport systems are being executed. An example in the field of transport infrastructure is the Channel Tunnel (Chunnel), linking the transport infrastructure of Western Europe with that of England. The quality of the latter link, when finished, can be evaluated in the light of the five critical success factors mentioned above. With respect to the hardware, the value of the Channel Tunnel would be greatly reduced when through-trains from the continent to e.g. London would be impossible. Partly, this reduced value might become reality when the French TGV is not allowed to attain its high speed on the English tracks due to the lack of compatible infrastructure on the English side of the Channel. As the Channel Tunnel will be used by through trains and by shuttle services, orgware is a very important factor too. The time tables must be organised in accordance with the time tables of the French and the English railways, while the shuttle services must be performed with a frequency that is sufficiently high to ensure its efficiency, which depends largely on the advantage of a strongly reduced travel time. Similar observations can be made regarding the finware (where the private financing of this project has caused

major concerns), the ecoware (in terms of protection of vulnerable areas crossed by new tracks) and software (in terms of sophisticated information systems).

The previous notions may also be helpful in investigating policy alternatives regarding infrastructure capacity. Capacity is not only a technologically determined given stock (measured in terms of hardware), but may also be determined by route guidance systems (software) or smart traffic regulations (orgware), especially from the viewpoint of a network system's operation.

In the light however, of all these remarks, it makes sense to pay more thorough attention to the notion of capacity of infrastructure, not only in line segments but also - and particularly - in multi-modal networks. Infrastructure expansion is usually advocated on the basis of lack of capacity of existing infrastructure. And normally the claim is made that new infrastructure investment would lead to a rise in capacity (even though we know that - according to Say's law 'supply generates its own demand' - after some time most new infrastructure will again manifest congestion phenomena). Therefore, the question is opportune: what is essentially capacity? And is it conceivable that capacity management, technologically upgraded capacity and intermodal flexibility contribute more significantly to the solution of capacity problems than straightforward expansion? And last but not least: are we able to assess - and charge to the user - the right price of capacity use?

A closer analysis of the concept of capacity brings to light that capacity is essentially a multi-faceted phenomenon which cannot easily be characterized by means of a single indicator, but needs to be investigated from multiple dimensions. Therefore, the above mentioned pentagon may also be helpful in identifying a proper definition of capacity (cf. Kreutzberger and Vleugel, 1992).

In the context of searching for a new concept of capacity the following reflection seems plausible. Capacity of infrastructure refers to the maximum volume of persons, goods, vehicles or messages that can use a given (part of) infrastructure in a given time period. The main question however is: what is maximum? This is not easy to answer, as for instance a road segment may already have reached its environmentally sustainable maximum, before it has reached its technical maximum. Consequently, the notion of capacity as a maximum use can only be delineated, if the criteria determining a maximum are specified. Following the pentagon approach, the following indicators are possible:

- technomax: the maximum volume that is possible, given the technical constraints on infrastructure.
- enviromax: the maximum volume that is allowable, given the sustainability constraints.
- orgmax: the maximum volume that is possible, given the regulatory system for the infrastructure at hand, and considering the quality expectations of travellers, transporters and shippers.

- economax: the maximum volume that may be expected, given the economic efficiency and financial criteria.
- infomax: the maximum volume that can be digested by the infrastructure, given the available information (on road conditions, congestion etc.).

These notions clarify the point that capacity has to be viewed as a multi-dimensional constraint, not only in a traditional technical sense, but much more in a broad sense in which policy intervention and human behaviour play a critical role. This leads to the important conclusion that capacity problems are not necessarily and predominantly solved by physical (hardware) expansion, but by a smart combination of different constituents that altogether make up a series of constraints on the use of infrastructure.

The previous considerations have been studied for four transport fields in the Netherlands (railways, road transport, inland waterways and airlines). These concepts appeared to be helpful in identifying the preponderant bottlenecks in existing infrastructures without leading immediately to a plea for physical expansion. In many cases, the limitations caused by technical or environmental barriers might even be overcome by a better organization of the transport system in a broad sense (e.g., better route guidance systems). Thus the focus on the multidimensionality of the capacity concept prevents us from thinking - exclusively or mainly - in terms of physical technical capacity. Even if expansion of infrastructure would be necessary, the question would arise: which type of infrastructure should be expanded and which type reduced, looking also into economic efficiency or performance indicators of infrastructure.

The above exposition has emphasized the need for an alternative view on network capacity (and hence network expansion). Rather than seeing capacity problems as a technical hardware problem (which might only be solved by means of material extension of existing infrastructure types), it seems plausible now that capacity has to be viewed from the multidimensional potential of a multi-modal network, with a focus on organization/management, financing, ecological sustainability and information systems access.

The most proper way to improve the current problematic situation of transport planning is not a straightforward expansion of conventional physical infrastructure, but either to upgrade existing infrastructure or to develop new transport systems without violating the constraints incorporated in our pentagon model. If we concentrate on the first option, the main strategies to be pursued here are (see Kreutzberger and Vleugel, 1992):

- to maximize the existing capacity reserves of infrastructure networks by improving their use;
- to increase the capacity of the existing infrastructure networks by improving their use.

The implications of these two strategies include inter

alia:

- avoidance of any unnecessary physical transport.
- operation of necessary physical transport systems against lowest social costs.
- (in the medium and long term) reducing the need for transportation by means of physical planning.

These concepts are elaborated in more detail in section 3.

3 Capacity and Use Management; Four Cases

3.1 Introduction

From the foregoing it becomes apparent, that capacity should be treated in the context of one or more (scenarios of) preconditions (constraints). Capacity is therefore not unique or constant; 'the' capacity of networks does not exist. Capacity has been defined in Section 2 as the maximum number of vehicles, persons or freight transported (in a certain time interval) between two or more destinations on a given infrastructure (segment).

Capacity has also a different meaning to the user and the network manager. For instance, levelling off peak use is beneficial for the network as a whole (the community of users, society), but the single user will not be pleased if he is prevented from using infrastructure at any time he or she wishes.

So there exists a potential dilemma between the wishes of the individual user (in terms of transport costs, time, routing etc.) and society, which may prevent the success of the two strategies mentioned in Section 2.

In the rest of this section a brief introduction into the use of max-scenarios for capacity and use management will be given for four transport systems; air-, road-, rail transportation and inland shipping. For each transport system we will present one or more max-scenarios, together with tentative indications - based on calculations - on their implications in terms of capacity and use. Side-effects are also described.

3.2 Air transport

Air transport differs from other modes of transport because it has the pattern of a chain; both arrival and exit of passengers and goods must follow strict routing. At most European airports capacity limits have been or are being reached in the near future. As physical extensions of capacity (e.g., more runways or new airports) are in most cases not a realistic option because of financial¹ and other restraints, (implicit) capacity management is one of the policy options. Capacity management may take various forms. We will consider the capacity effects of homogenizing the fleet of arriving and

¹ For instance, the latest plans for doubling the capacity of Schiphol Airport imply investing some 22 mld. Dfl.

departing airplanes, and enlarging the scale of the fleet (e.g., larger airplanes). Homogenizing means that airplanes with unequal flight characteristics are replaced by planes with more or less equal ones. Putting a small airplane behind a larger one on a runway requires more distance, because of (tailwind) turbulence. Therefore separation intervals (time) between two larger airplanes are less than those between a large and a small one. The following table indicates the gain in capacity as a result of homogenizing. Since 34 heavy airplanes may transport the same transport weight as 20 heavy plus 20 medium ones, 15 % less airplanes are needed.

Table 1: The effect of homogenizing on landing capacity

<i>Heterogeneous traffic</i>				
(1)	(2)	(3)	(4)	(5)
H-M	2.15	27	14 * 0,2 + 13 * 0,14	4.62
M-H	1.48	40	20 * 0,14 + 20 * 0,2	6.80
<i>Homogeneous traffic</i>				
H-H	1.74	34	34 * 0,2	6.80
M-M	1.45	41	41 * 0,14	5.78
Remarks:				
(1)	Traffic mix (leader and follower; first airplane-second airplane), H=heavy: > 0,14 metric tons, M=medium: 7000 kg < M < 0,14 metric tons).			
(2)	Minimum separation (for the year 2000) in flight minutes.			
(3)	Maximum airplane capacity per hour (rounded).			
(4)	Maximum starting weight in mln. tons; these figures may differ from the maximum weight of passengers/freight.			
(5)	In practice airplanes will arrive irregularly. Besides that, a mix of smaller and larger airplanes will arrive. Delays are also important. In sum, homogenizing is not easily reached in actual practice.			
(6)	The gain in capacity will be much larger, since the actual landing weight of jumbojets is much larger than 200.000 kg.			

Source: Kreutzberger and Vleugel (1992, Table 15, p. 135).

In practice, full homogenizing and scale increase are not always feasible, but partial developments cannot be judged as completely unrealistic. The side-effects of homogenization include, inter alia, investments in fleet replacement and in other parts of airport infrastructure (e.g. terminal capacity). For airlines, another major problem is how to reach the optimal (economic) percentage of airplane-load on all destinations, if a certain airplane type would be more or less prescribed or imposed by airport managers.

3.3 Road transport

Capacity restraints are very common in road transport. There is a number of ways to relieve this problem. Well-known measures include, inter alia, traffic management, road pricing and parking restrictions; these are all infrastructure-related. Another option is vehicle-related, namely increasing the weight of lorries. Caff (1988) indicates, that "In Britain, following the increase in the maximum gross vehicle weight from 32.5 tonnes to 38 tonnes in 1983, it is estimated that 5 000 fewer heavy lorries are now used. This has meant a reduction of about 250 million miles travelled through Europe by goods vehicles (...)". Increasing the vehicle weight may therefore increase the transport capacity of roads, because less vehicles are needed². An important negative side-effect is however, the fact that longer trucks especially in cities are hard to manoeuvre and therefore may cause extra accidents. Interesting, but not surprising, is also the comparison of normal and capacity-maximizing express way usage by travellers. Homogenizing and scale increasing of the vehicles by introducing bus transport as the exclusive transport system on express ways pushes up the transport capacity of express ways. According to Bexelius (1989), the capacity of express ways would rise by a factor of eight if big buses were chosen. Of course, exclusive bus-transport does not respond to all the needs of passenger transportation.

3.4 Inland shipping

Inland shipping in the Netherlands has not been confronted with capacity constraints on the lockless waterways yet. However, this can easily change during the next decade, if the transport forecasts become reality. On waterways with locks - common in most European countries and also in parts of the Netherlands - the locks are the most important bottlenecks, as their capacity usually is only a fraction of that of the surrounding waterways.

In contrast to the other transport systems, research and planning activities are hardly focused on capacity issues; in stead, they are restricted to the relation between vessel size and waterway characteristics. Nevertheless, the restricted information about the capacity factors enables us to give the following indications on the effects of a more efficient use of waterways. The capacity of an existing lockless link can be doubled or more (depending on the current water levels of waterways) by homogenizing vessel traffic, increasing vessel size, and changing the other conditions of use (e.g., the introduction of advanced traffic management systems, increased manoeuvrability of ships and higher speeds of ships). On waterways with locks other factors determine the possible capacity. The aim is to maximize the use of a lock in a certain time interval. This implies that not the biggest vessel, but the vessel size which fits best in the lock without causing too

² The same effect can be established by increasing the vehicle length.

much entering and leaving time leads to the highest increase in capacity.

An important strategy for a better cost-benefit relation of waterways implies using it more efficiently without changing the capacity. This may include a spread of transport in time, thereby lifting off capacity constraints and using existing capacity reserves, or to avoid navigation with a low percentage of ship-load or empty ships.

3.5 Rail transportation

The support of public passenger transportation by governments and - in the future also of rail freight traffic - has made it necessary to increase the capacity of rail infrastructure in the Netherlands. This is done by physical expansion of the network, incurring huge investments. Nevertheless, it is not clear whether the extra capacity is sufficient to meet all transport requirements. In parts of the Netherlands physical expansion of the network (wider profiles or new links) are also difficult to integrate in the existing urban and natural landscape. In sum, there are plenty of reasons to think about alternatives for expanding the network. Using the infrastructure more efficiently and increasing the rail capacity by means of rail management are likely to be very attractive alternatives.

Rail capacity depends on the loading and riding characteristics of trains, the degree of homogeneity among train types used, the quantity and quality of the installed signalling systems, the distance between facilities where trains can overtake each other, the quality of operation systems (e.g., maintenance), the speed, acceleration and brake characteristics of trains, the functionality of pedestrian areas in railway stations, and the loading capacity of wagons and trains.

Homogeneity means that all or most trains have the same number of stops and the same speed in order to avoid the necessity of passing each other. A high capacity might be attained by admitting only one train type with an optimal acceleration and brake performance, by reducing incident reserves (by increasing the quality of maintenance), and by promoting a higher loading capacity of trains. If all these conditions for using the rail infrastructure were realized, then it would be possible to increase the capacity of rail infrastructure to about 40 trains per hour (both directions). These figures are the results of a restricted simulation (analyzed in Kreutzberger and Vleugel, 1992). The advantages of such a high traffic intensity are significant, if one considers that the present capacity in the Netherlands varies between 8 (mixed mode), 12 (stopping trains only) or 16 (intercity trains only) trains per hour and direction. Of course, this high capacity requires high investments, inter alia in new traffic management systems (including new signal systems in cabins). It may also lead to the closure of some stations, which calls for compensating investments in local public transportation. However, the costs of these changes should be compared with the

investment savings in physical expansion of the railway network, and with the possible advantage of a higher quality of life when avoiding physical expansion.

4 Strategic Conclusions

In this paper we have examined the use of so-called max-scenarios in capacity and use management of infrastructure; capacity is a constraint-related phenomenon. It became clear that these scenarios may be important planning tools. Both types of management may become increasingly important as a replacement for the usual - but increasingly socially unacceptable - way of physically expanding infrastructure networks.

It became also clear, that capacity should not only be considered in relation to a separate infrastructure segment (the main view in the past), but as a feature of a multi-layer and multi-modal network. For example, capacity problems (such as peak hour congestion) in some modes may be overcome by inter-modal substitution and complementarity. The identification of the optimal mix of necessary infrastructure modes in view of reaching given objectives (the so-called packaging problem) is a major issue in this context.

From the viewpoint of system-wide network optimization, it makes sense to pay particular attention to specific bottlenecks, such as transit points, variety in interaction/communication speed, intermodal connections, information systems regarding network operation, peak load and peak use, flexible working hours, new logistic systems, the position of mainports, standardisation in transport systems technology, hierarchical function decision in networks etc. Combined transport may often be regarded as an efficient way of overcoming current limits, by improving intermodal transit potential, rather than physically expanding the whole infrastructure. This allows also a much better use of existing capacity, so that through chain connections the above mentioned socio-economic equity problem of limited network access can be relaxed.

The conclusion from the above observations is that there is a need for strategic and anticipatory research, by taking long-run sustainability criteria as a point of departure and linking design and operation of networks to these criteria. This would also bring to light the (potential) success and failure of transport policy in different regions and nations in Europe.

5 Epilogue

The optimization of capacity and traffic efficiency by varying the conditions of using infrastructure brings us to the environmental or background conditions of the functioning of infrastructure. This is because the presented possibilities for changing infrastructure use require great amounts of investments in the vehicle fleets, possibly also in the shipping business, distribution and logistics and even in housing and working locations. Next to that, operational costs of transportation may increase, for example, because of raising the speed of vessels. A higher efficiency by means of spreading transport in time also forces to changes in socio-economic structures (e.g., reducing sectoral privileges or abolishing national protective policies). In other words, the balance between actors who benefit and lose is likely to change. Success in saving investments by increasing the efficiency of infrastructure with less physical expansion of the network requires equalization of advantages and disadvantages between actors. This of course, is not the easiest challenge for politics.

REFERENCES

Bexelius, S., 1989, Vier Scenario's voor het Verkeer en Vervoer in 2010/2015, Bijdrage aan de Verkeerskundige Werkdagen 24-25 May, 1989.

ECMT, 1986, International Traffic and Infrastructural Needs, Paris.

ERT, 1991, Missing Networks, a European Challenge: Proposals for the Renewal of Europe's Infrastructure, ERT Secretariat, Brussels.

Himanen, V., P. Nijkamp and J. Padjen, 1991, Environmental Quality and Transport Policy in Europe, Research Memorandum 1991-97, Free University, Amsterdam.

Kreutzberger, E., and J.M. Vleugel, 1992, Capaciteit en Benutting van infrastructuur, Randvoorwaarden van de infrastructuurbenutting in het wegvervoer, railvervoer, luchtvervoer en de binnenvaart, Delft, Delft University Press.

Maggi, R., and P. Nijkamp, 1991, Missing Networks and Regional Development, Research Memorandum, Free University, Amsterdam, 1991.

Nijkamp P., Reichman, S. & M. Wegener, 1990, Euromobile, Avebury, Aldershot.

Vleugel, J.M. en P. Nijkamp, 1991, Policy Strategies for Missing Networks in Europe, in: H.G. Smit (ed.), European Transport Colloquium 1991, Transport Developments in an Integrating Europe, INRO-TNO/ETC, Delft, 1991, pp. 189-207.

- | | | | | | |
|---------|---|--|---------|---|--|
| 1991-1 | N.M. van Dijk | On the Effect of Small Loss Probabilities in Input/Output Transmission Delay Systems | 1991-21 | J.M. Sneek | On the Approximation of the Durbin-Watson Statistic in $O(n)$ Operations |
| 1991-2 | N.M. van Dijk | Letters to the Editor: On a Simple Proof of Uniformization for Continuous and Discrete-State Continuous-Time Markov Chains | 1991-22 | J.M. Sneek | Approximating the Distribution of Sample Autocorrelations of Some Arima Processes in $O(n)$ Operations |
| 1991-3 | N.M. van Dijk
P.G. Taylor | An Error Bound for Approximating Discrete Time Servicing by a Processor Sharing Modification | 1991-23 | B. Hanzon
R. Hut | New Results on the Projection Filter |
| 1991-4 | W. Henderson
C.E.M. Pearce
P.G. Taylor
N.M. van Dijk | Insensitivity in Discrete Time Generalized Semi-Markov Processes | 1991-24 | R.J. Veldwijk
E.R.K. Spoor
M. Boogaard
M.V. van Dijk | On Data Models as Meta Models, An Application Designers Point of View |
| 1991-5 | N.M. van Dijk | On Error Bound Analysis for Transient Continuous-Time Markov Reward Structures | 1991-25 | C. Camfferman | Some aspects of voluntary disclosure |
| 1991-6 | N.M. van Dijk | On Uniformization for Nonhomogeneous Markov Chains | 1991-26 | D. van der Wal | Monetary Policy Credibility: The Experience of the Netherlands |
| 1991-7 | N.M. van Dijk | Product Forms for Metropolitan Area Networks | 1991-27 | J.A. Vijlbrief | Unemployment Insurance in a Disequilibrium Model for The Netherlands |
| 1991-8 | N.M. van Dijk | A Product Form Extension for Discrete-Time Communication Protocols | 1991-28 | H.L.M. Kox | The "Non-Polluter gets paid" Principle for Third World Commodity Exports |
| 1991-9 | N.M. van Dijk | A Note on Monotonicity in Multicasting | 1991-29 | H. Tijms | A New Heuristic for the Overflow Probability in Finite-Buffer Queues |
| 1991-10 | N.M. van Dijk | An Exact Solution for a Finite Slotted Server Model | 1991-30 | B. Hanzon | On the Estimation of Stochastic Linear Relations |
| 1991-11 | N.M. van Dijk | On Product Form Approximations for Communication Networks with Losses: Error Bounds | 1991-31 | R.L.M. Peeters | Comments on Determining the Number of Zeros of a Complex Polynomial in a Half-Plane |
| 1991-12 | N.M. van Dijk | Simple Performability Bounds for Communication Networks | 1991-32 | A.A.M. Boons
H.J.E. Roberts
F.A. Roozen | The Use of Activity-Based Costing Systems in a European Setting: a case study analysis |
| 1991-13 | N.M. van Dijk | Product Forms for Queuing Networks with Limited Clusters | 1991-33 | J.C. van Ours | Union Growth in the Netherlands 1961-1989 |
| 1991-14 | F.A.G. den Butter | Technische Ontwikkeling, Groei en Arbeidsproductiviteit | 1991-34 | R. van Zijp | The Methodology of the Neo-Austrian Research Programme |
| 1991-15 | J.C.J.M. van den Bergh, P. Nijkamp | Operationalizing Sustainable Development: Dynamic Economic-Ecological Models | 1991-35 | R.M. de Jong
H.J. Bierens | On the Limit Behaviour of a Chi-Square Type Test if the Number of Conditional Moments Testes Approaches Infinity Preliminary Version |
| 1991-16 | J.C.J.M. van den Bergh | Sustainable Economic Development: An Overview | 1991-36 | K. Burger
J.W. Gunning | Gender Issues in African Agriculture: Evidence from Kenya, Tanzania and Côte d'Ivoire |
| 1991-17 | J. Barendregt | Het mededingsbeleid in Nederland: Konjunkturgevoeligheid en effectiviteit | 1991-37 | M. Boogaard
R.J. Veldwijk
E.R.K. Spoor
M.V. van Dijk | On Generalization in the Relational Model |
| 1991-18 | B. Hanzon | On the Closure of Several Sets of ARMA and Linear State Space Models with a given Structure | 1991-38 | R. Dekker
E. Smeitink | Preventive Maintenance at Opportunities of Restricted Duration |
| 1991-19 | S. Eijffinger
A. van Rixtel | The Japanese Financial System and Monetary Policy: a Descriptive Review | | | |
| 1991-20 | L.J.G. van Wissen
F. Bonnerman | A Dynamic Model of Simultaneous Migration and Labour Market Behaviour | | | |